**Report 98-101**

**Train 721**

**heat buckle derailment**

**near Scargill**

**5 February 1998**

## Abstract

On Thursday, 5 February 1998 at about 1630 hours, Train 721, a southbound Picton to Christchurch express freight was near Scargill when the locomotive engineer noticed a buckle in the track ahead. He was unable to slow the train significantly in the limited distance available and although the locomotive and the three leading wagons traversed the buckled track, the following eleven wagons became derailed before the train came to a stop. A safety issue identified was the failure of the safety system to achieve adequate protection of a predictable weak spot.

# Transport Accident Investigation Commission

## Rail Incident Report 98-101

| | |
|---|---|
| **Train type and number:** | Express freight 721 |
| **Date and time:** | 5 February 1998, at approximately 1630 hours |
| **Location:** | Near Scargill at 79.40 km Main North Line |
| **Type of occurrence:** | Derailment resulting from a track heat buckle |
| **Persons on board:** | Crew : 1 |
| **Injuries:** | Nil |
| **Nature of damage:** | 100 m of track damage; 11 damaged wagons |
| **Investigator-in-Charge** | R E Howe |

# 1. Factual Information

## 1.1 Narrative

1.1.1 On 5 February 1998, Train 721 was a rostered southbound Tranz Rail Limited (Tranz Rail) express freight operating between Picton and Christchurch.

1.1.2 The train consist was locomotive DF7010 and 18 wagons. It was crewed by a single locomotive engineer (LE) and departed Picton at 0945 hours.

1.1.3 At approximately 1630 hours Train 721 was 6 km south of Scargill and the LE stated he was travelling at 75 km/h (the maximum allowable speed for express freight trains being 80 km/h) when he noticed a "quite bad" buckle approximately 20 m ahead. The buckle was in a 640 m radius right hand curve (in direction of travel). Appreciating that he would not be able to stop the train in the limited distance available, he applied the brakes, "and hit the deck" in anticipation of the train becoming derailed as it traversed the misaligned area.

1.1.4 The LE observed the buckle was to the left (outside leg of the curve) over a distance of approximately 15 m.

1.1.5 The locomotive and the following three wagons traversed the buckled track without derailing but the next eleven wagons became derailed before the train was brought to rest. The last four wagons on the train stopped just short of the buckled area and remained on the track.

1.1.6 The point of derailment (POD) was at 79.40 km, Main North Line (MNL).

1.1.7 Northbound Train 776 was the last train through the area at approximately 1600 hours and the LE of this train stated there was no abnormality in the track at that time.

## 1.2 Track details

1.2.1 The track in the area of the derailment consisted of 50 kg/m rail and was fixed by "Pandrol" fastenings onto concrete sleepers in sound condition. The track either side of the derailment area was in sound condition with all of the fastenings in place and tight. The track was laid in 1978.

1.2.2 The rail was originally installed as continuously welded rail at an unknown neutral temperature and it was not until March 1995 that the area was destressed to the then current neutral range of 23°C to 35°C to minimise heat induced stresses within the rail.

1.2.3 The destressing return of 6 March 1995 gave details of the action taken at that time to neutralise the stresses within the CWR from 79.10 km to 79.85 km MNL. The return recorded a rail temperature of 30°C.

1.2.4 There was a variation in some of the gauge plates that were used in conjunction with the "Pandrol" fastenings to provide insulation and fix the gauge of the track. On one rail the plastic gauge plates were overlaid with a cast steel cover plate, while on the other they were all plastic. However there was no evidence of differential movement between rail and sleeper as a result of these dissimilar fastenings.

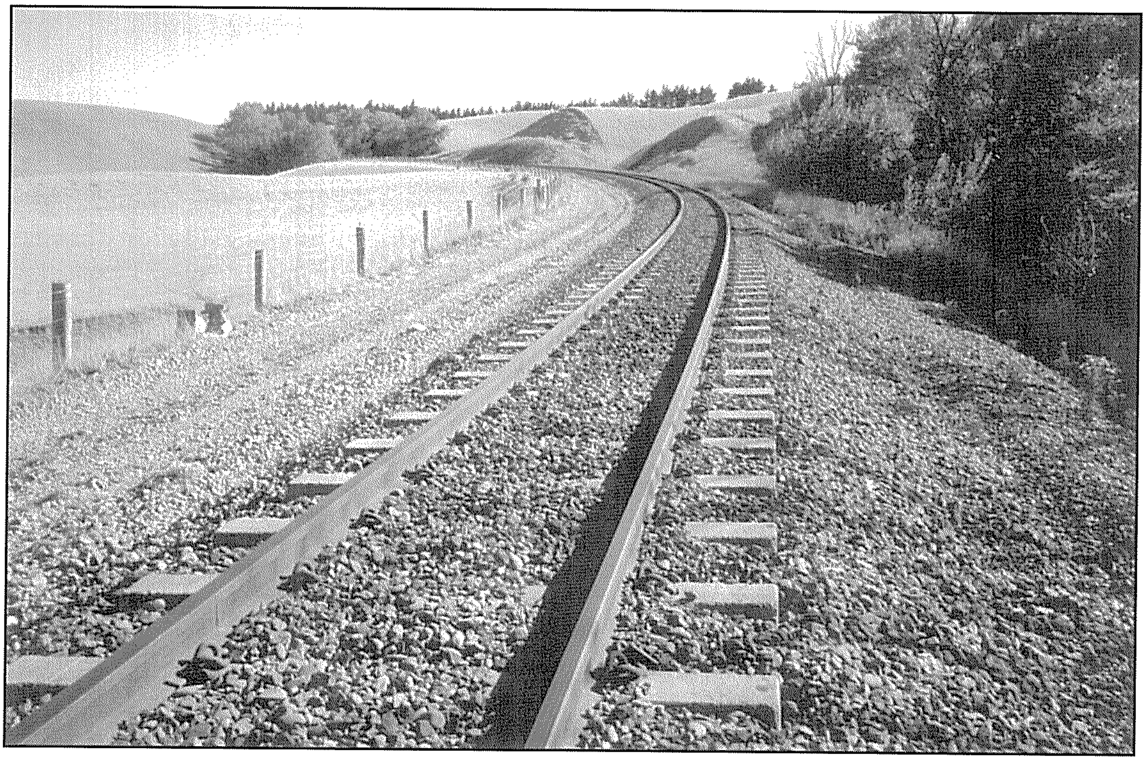


**Figure 1**
**Ballast section adjacent to point of derailment**

1.2.5 The track ballast used in the area of the derailment was clean crushed river gravel, well drained and with a minimum depth of 250 mm below the underside of the sleepers. The ballast section at the actual buckle site could not be established because of the track damage caused by the derailment. However there were areas of track immediately to the north of the derailment where the ballast section was inadequate, both at the top level of the sleeper and from the outside face at the sleeper. (See Figure 1.)

1.2.6 The minimum new ballast section for CWR track as stipulated in Tranz Rail's Code Supplement CSP/55 for straight track and curves greater than 400 m radius is shown in Figure 2. Tranz Rail advised that the ballast profile, as distinct from ballast depth, was also the minimum standard for maintaining existing track.

1.2.7 The Track Inspection Diary of 20 January 1997 had a comment from the line inspection dated 3 February 1995:

> 79.040 km to 79.850 km 640L pinnacle track and overlifted misc locations
> __________ weak shoulders intermit[1]

and was listed as a priority 2 correction. Priority 2 was the second highest priority for action, but had no specific time defined by which action had to be taken. No work had been carried out on ballast profile improvement since February 1995 although the Area Track and Structures Manager stated that he had attempted, without success, to obtain the services of Tranz Rail's ballast cleaner to lower the track.

1.2.8 The Area Track and Structures Manager, the Ganger and the Line Inspector stated that in their opinion the ballast section was sufficient and they could not understand why the track buckled, notwithstanding the high temperature.

1.2.9 Tranz Rail Code CSP/31 stipulated the following sleeper standards for CWR track:

a) On straights and curves of radius down to and including 1000 metres
- 75% of sleepers holding longitudinally effectively.

b) On curves of radius 400 to 1000 metres
- 100% of sleepers holding longitudinally effectively.

c) On curves of radius 200 to 400 metres
- face resleepered with concrete sleepers.

1.2.10 The alignment and level of the track either side of the derailment damaged area was to a high standard. The last track recording car run of 7 October 1995 showed track parameters well within allowable tolerances.

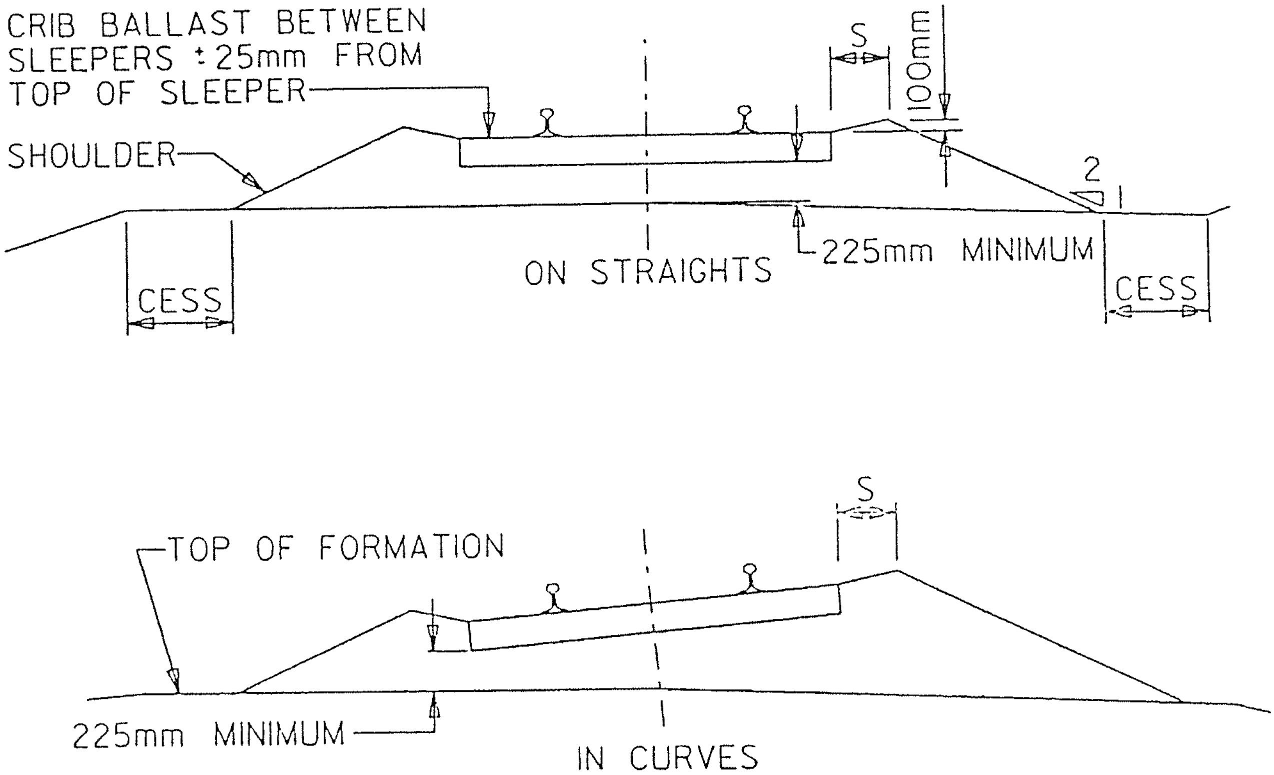
1.2.11 The area of track at the derailment site did not have any previous history of track buckles.

### 1.3 Site details

1.3.1 The track was on a general 6.5 km down grade of 1 in 70 (in direction of travel), with the track buckle occurring on a short section of level track approximately 2 km down the grade.

---

[1] This entry relates to the curve on which the derailment occurred. It indicates the track was sitting too high on the embankment (pinnacle track) due to successive tamping raising track level and leaving insufficient embankment width to provide the required ballast profile. As a result of this the curve had intermittent areas of weak shoulders.




MINIMUM SHOULDER WIDTH 'S'

| | |
|---|---|
| ON STRAIGHTS AND CURVES 400m RADIUS AND OVER, BOLTED AND WELDED TRACK. | 350mm |
| ON CURVES UNDER 400m RADIUS | |
| BOLTED TRACK | 350mm |
| WELDED TRACK | 450mm |

Minimum New Ballast Section for Class A, B and C lines

**Figure 2**
**Tranz Rail ballast profile requirements**

1.3.2 The derailment occurred near the centre of the 640 m radius right hand curve.

1.3.3 The railway alignment in the Scargill area follows a line of cuttings and fillings through undulating, rolling countryside. In the area of the track buckle, the alignment was built up on an embankment approximately 25 m deep between cuttings either side. (See Figure 3.)

## 1.4 Weather conditions

1.4.1 The North Canterbury area had been experiencing severe drought conditions for some weeks and air temperatures had been consistently high over a considerable length of time.

1.4.2 Air temperatures recorded in the area by the Meteorological Service of New Zealand Limited showed the following maximums taken at the nearest recording stations, Waipara and Waipara West. The actual temperature at the derailment site may have varied from these temperatures due to microclimate variations in the area.

| | Waipara (15 km away) | Waipara West (30 km away) |
|---|---|---|
| Wednesday 4 February | no data | 32.6°C |
| Thursday 5 February | 35.0°C (max at 1716 hrs) | 35.2°C |

The temperature at Waipara West had reached 35°C on only one other occasion since 1990 and had exceeded 30°C on only four occasions, since 1990.

## 1.5 Patrols and inspections

1.5.1 Tranz Rail Code Instruction P.20 stipulated that gang lengths were to be patrolled on a regular basis to ensure safety for the passage of trains. There was a requirement to patrol the MNL twice per week with a maximum of five days between patrols. These patrols had been carried out as required in the area of the derailment, the last one on the morning of the buckle.

1.5.2 Code Instruction P.22 made provision for special patrols to safeguard the passage of trains in times of possible danger and included the possibility of obstruction due to storm, flood, earthquake, fire, gales, track damage due to defective dragging wagon equipment or the possibility of a track buckle.

1.5.3 Code Instruction P.90 stipulated the precautions to be taken in hot weather when rail temperatures were high, and had two categories, "areas of known high risk", and "areas not of high risk".

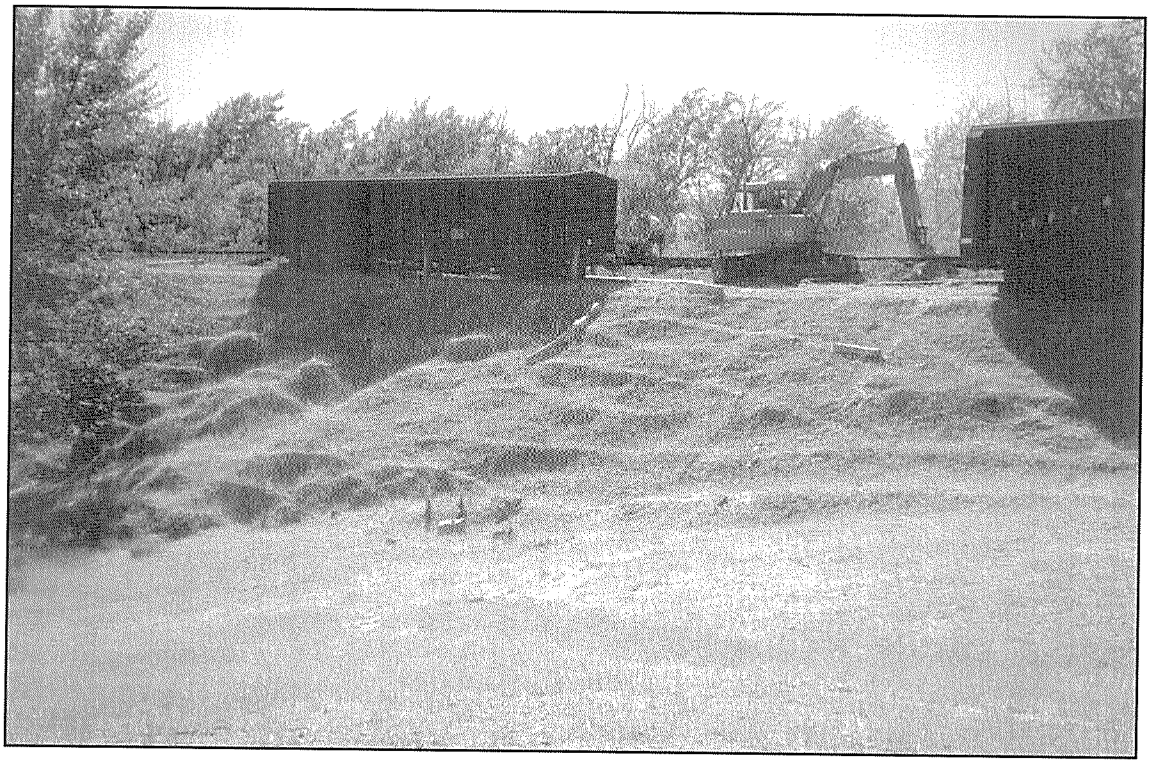


**Figure 3**
**General view of the embankment**

1.5.4 For "areas of known high risk", the precautions to be taken were:

1. When rail temperatures are increasing and exceed 40°C reduction of train speed must be considered.

2. If rail temperatures exceed 50°C or other unstable track conditions are evident, consideration must be made to stop trains or pilot trains.

3. All trains (including passenger) should have speeds reduced to 40 km/h, or lower depending on site conditions, when rail temperature is 40°C and still rising. This applies to track that has a high risk of buckling or that has a known problem which has not been corrected.

4. Track staff are to monitor rail temperatures and advise train control when speed restrictions are to be enforced. They will also advise train control when speed restrictions are to be lifted unless otherwise shown on a train advice.

5. Patrols are to be carried out. Refer clause P 22.

Track affected:

1. That track identified and listed will have speed restrictions applied as above.

2. Other track that will be affected is:
   - track recently disturbed by tamping
   - track with a reduced number of effective fastenings due to track work being carried out or deteriorating track condition. Refer also to CSP/38.

1.5.5 Train Advice No. 600 gave details of identified high risk areas (Appendix 1). The derailment site at 79.40 km was not included as it was considered to be stable and "not of high risk".

1.5.6 For "areas not of high risk", Code Instruction P.90 stipulated:

> Track that is deemed to be not a high risk may also have speed restrictions applied when rail temperatures are well in excess of 40°C. This will be at the discretion of the Track and Structures Manager (T&SM) and in consultation with Manager Track Maintenance (MTM).

1.5.7 Because of the significance of rail temperature on the stability of the track, line gangs and track patrollers were supplied with rail temperature gauges which gave a quick, easy and accurate measure of the rail temperature.

1.5.8 In areas where the track was known to be susceptible to high temperatures, or where the track was sub-standard in some form, precautionary temporary speed restrictions (usually 40 km/h) were imposed where the rail temperature exceeded a given level for the area. These restrictions were known as "Heat 40's" and the areas so delineated were separately identified. The "Heat" boards were permanently erected to cover the area concerned and were activated on advice from the track ganger to train control who would immediately issue a train advice to traffic in the area.

1.5.9 The track patroller for the length recorded a rail temperature of 46°C at approximately 1200 hours on 5 February, during his normal track patrol. This measurement was taken at 94.5 km MNL (5.1 km north of the heat buckle). He confirmed with Train Control that the 40 km/h speed restrictions detailed on Train Advice No. 600 (Appendix 1) had already been activated by the length ganger.

1.5.10 A member of the gang recorded rail temperatures of 47°C and 51°C at Amberley and Waipara at approximately 1530 hours on 5 February.

1.5.11 The rail temperature taken at the site at 1800 hours (1.5 hours following the derailment) was 53°C.

1.5.12 Although there was a recognition by local track staff prior to the derailment that the rail temperatures were unusually high in the area, they did not consider it was necessary to initiate the action required to apply a temporary speed restriction in accordance with Code Instruction P.90 for the pinnacle track with weak shoulders at the 79.4 km.

1.5.13 Because of the high air temperature a special patrol in accordance with Code Instruction P.22 had been arranged to run ahead of Train 701, the southbound *Coastal Pacific* express. This patrol, which would have covered the full gang length prior to the arrival of the passenger train, had reached Waipara at the time of the derailment.

### 1.6 Personnel

1.6.1 All staff associated with track inspections and maintenance were appropriately qualified long serving staff with years of local knowledge in the area.

### 1.7 Event recorder

1.7.1 No locomotive log was available to confirm the speed of the train and other operating details as the event recorder was not working.

## 2. Analysis

### 2.1 Continuously welded rail (CWR) and track buckles

2.1.1 CWR track is formed by welding together lengths of rail to eliminate the bolted joints between them. It is a well established world wide practice and was first used in New Zealand in the early 1970s. Because all the rail joints have been removed and provision for temperature expansion therefore eliminated, it is necessary to take special measures to resist the effects of temperature variations on the rails. In addition to specific requirements for the ballast, sleepers, and fastenings, it is essential that CWR is formed so that there is no stress in the rails at a defined temperature, usually called the neutral temperature.

2.1.2 The neutral temperature has been set taking into account the likely maximum and minimum rail temperatures that may be encountered, so that maximum compressive and tensile stress caused by hot and cold weather respectively, can be coped with safely in the track. With progressive research on CWR, the effective neutral temperature has been increased to decrease the compressive stresses induced by heat.

2.1.3 The heat induced forces in rails are significant. For every 1°C rise in temperature above the neutral temperature, a longitudinal force of 2.65 t is generated within track laid in 50 kg/m rail. Thus for a 40°C rise in temperature above neutral (the theoretical design maximum for New Zealand conditions), a force of 106 t would be experienced at a maximum rail temperature of 67°C.

2.1.4 Various factors that have to be taken into account to ensure that CWR track is kept stable within the design temperature range include:

- the rail temperature
- ballast grading
- ballast profile
- sleeper condition
- fastening integrity (the ability of the fastening to hold the rail firmly)
- buckling history
- bridges, level crossings, or other obstructions at which track is effectively anchored and adjacent track can bunch up if the fastenings allow longitudinal rail creep
- presence of warning signs (misalignments in hot weather, rail creep)
- recent track disturbances (tampers, resleepering, derailment damage)
- weather patterns (first hot day after cool weather, exceptionally hot days, lack of wind)
- microclimates (sheltered valleys, cuttings, windbreaks)
- track gradient (rail creep can occur downhill, contributing to buckling at the bottom of a grade)
- curvature
- traffic flow and braking patterns.

## 2.2 Temperature

2.2.1 The air temperatures recorded at weather stations on the day were in the region of 35°C and variations beyond this figure were possible depending on the microclimate within the region. Rail temperatures of 46°C to 51°C were recorded on the gang length prior to the incident. A rail temperature of 53°C was recorded at the site at 1800 hours following the incident. The rail temperature at the site was “well in excess of 40°C” (Code Instruction P.90), and likely to have exceeded 50°C, at the time of the derailment.

## 2.3 Destressing

2.3.1 The destressing carried out in the area of the derailment on 6 March 1995 was in conformity with code practices. The rail temperature on the day (30°C) was within the neutral temperature range (27°C to 35°C) and no rail extension was necessary.

2.3.2 Although destressed in 1995 it is likely that the effect of traffic and grade since then had resulted in an increase of compressive stress in the vicinity of the derailment which would have decreased the factor of safety against buckling.

## 2.4 Ballast profile

2.4.1 With CWR track, it is the adequacy of the ballast section which restrains the sleepers and thus assists in resisting lateral and longitudinal movement of the track under compressive stress.

2.4.2 The depth of ballast below the bottom of sleeper on either side of the derailment site conformed with the depth requirements of Tranz Rail's Code and it is likely that similar depths existed through the derailment site itself. However, the shoulder ballast section immediately adjacent to the POD was deficient and it is likely this deficiency existed through the derailment site.

2.4.3 The deficient ballast shoulder section had developed as a result of a "pinnacle" track situation. The POD was on an embankment formation between cuttings, and to compensate for differential settlement over the years the track had been progressively lifted over the embankment with additional ballast added to achieve this. This caused gradual deterioration of the ballast shoulder profile and resulted in the deficient profile as shown in Figure 1.

2.4.4 In view of these deficiencies it was surprising that each of the track staff interviewed considered the ballast profile through the curve to be adequate to withstand buckling, although consideration had been given for a need for a ballast cleaner to lower the track.

## 2.5 Track gradient

2.5.1 The derailment occurred on a general downgrade of 1 in 70. By main line standards this gradient is relatively steep.

2.5.2 The derailment occurred at a short, near level, plateau at approximately one third down the grade. This is a likely position for increased compressive stress in the rail due to the increase in resistance to downhill movement of the rail provided by the level track.

## 2.6 Downhill rail movement

2.6.1 The longitudinal forces transferred to the head of the rail with heavy downhill braking on steep grades have a tendency to move the track downhill over a period of time. This can cause the track at the base of a grade to "bunch up" and be subject to greater compressive forces than would otherwise be the case. Although such downhill movement is rare on track with "Pandrol" fastenings this may have been a contributing factor to the stress in the rails at the time of buckling.

## 2.7 Track curvature

2.7.1 The compressive forces developed in CWR track as a result of hot weather are best resisted (all other things being equal) in straight track. In this situation the track is analogous to a column and is able to accommodate greater force so long as it is kept straight. With curved track or track that has been subject to lateral movement, the ability to resist buckling is reduced.

2.7.2 The resistance to buckling of CWR track becomes more important on curved track as the radius of the curve reduces. This is recognised in the higher sleeper standard required for CWR track that is curved. The CWR at the derailment site was laid on concrete sleepers in a curve of 640 m radius and met the requirements for sleepers. However the deficient ballast shoulder in an area of lower buckling resistance created a predictable weak spot.

## 2.8 Track stability

2.8.1 The track staff in the area considered the track was in good condition and this was supported by the track recording car output and riding characteristics. There appeared to be common lack of appreciation of the potential cumulative affects of temperature, gradient, ballast section and curvature on track stability.

## 3. Findings

Findings and safety recommendations are listed in order of development and not in order of priority.

3.1 The train was being operated normally prior to the incident.

3.2 Rails, sleepers and fastenings were in good condition and well maintained and ballast depths and quality were to standard.

3.3 It is highly likely that the shoulder ballast profile was significantly and visibly deficient, especially to the outside leg of the curve, at the POD.

3.4 It is most unlikely that the rail temperature at the time of the buckle was outside the design temperature range for CWR. The temperature induced stresses within the track were likely to have been higher than desirable for the temperature due to the effect of down-hill "bunching" of the track over a period of three years.

3.5 The track buckled because of the high compressive stress induced in the rails due to the temperature and the site related factors, and the reduced resistance provided by the ballast profile, particularly on the outside of the curve.

3.6 No discretionary speed restriction had been considered necessary in accordance with Code Instruction P.90 as a result of the unusually hot weather and recorded rail temperatures in the area exceeding 50°C.

3.7 Track staff displayed a lack of in-depth knowledge of the site factors and deterioration in track standards which could reduce the stability of CWR in hot weather.

3.8 A history of stable track in the derailment area had given track staff an unjustified confidence as to the track's ability to withstand high temperatures.

## 4. Safety Actions

4.1 The Commission's investigation into a heat buckle derailment at Edendale on 13 December 1994 (Railway Occurrence Report 94-127), led to a number of safety actions and safety recommendations. Some were specific to the Edendale site but others were more general.

4.2 Actions taken by Tranz Rail (then New Zealand Rail Limited [NZRL]) immediately following the Edendale derailment included:

- A new national priority list was compiled for destressing 38 m and 76 m rail lengths and longer lengths of CWR based on age and type of components and factors such as grade, buckling history and particular local maintenance problems. NZRL's intent was to complete action on this list in priority order within two years. The Scargill site had been destressed as part of this programme.
- NZRL reviewed training needs and introduced a specific retraining programme for track and structures managers and gangers, which included consideration of track buckles.

## Appendix 1

TRANZ RAIL LTD

TRAIN ADVICE NO.600 — Network Services
(Semi-permanent) — WELLINGTON 5 February 1998

---

CANCELLATION

Train Advice No.131 dated 16 January 1998 re Special Temporary Speed Restrictions for the Main North Line is CANCELLED.

---

To be read in conjunction with Train Advice No.5559 (Group Operations, Semi-permanent) dated 2 October 1997 re arrangements for Special Temporary Speed Restrictions.

SPECIAL TEMPORARY SPEED RESTRICTION AREAS.

Commencing FORTHWITH and continuing until further advised the following instructions will operate:

When advised by Train Control the speed of ALL trains over portions of the line shown below MUST NOT EXCEED 40 KM/H, (except where a lower speed restriction is in place at/within the specified restriction). The restrictions will normally cease at 2100 hours unless Train Control is otherwise advised by the respective Ganger in charge.

MAIN NORTH LINE

| Metrages between km km | Locations Between | DATE OF OPERATION (to be completed by Train Control/Locomotive Engineer) | |
|---|---|---|---|
| LENGTH GANG MN2 | | Tick in box if restrictions are:- | |
| | | on | off |
| 94.20 to 94.50 | Scargill and Tormore | | |
| 134.80 to 138.00 | Spotswood and Ferniehurst | | |
| LENGTH GANG MN4 | | on | off |
| 163.80 to 164.96 | Clavery and Oara | | |
| 213.20 to 215.20 | Hapuku and Pines | | |
| 218.50 to 219.80 | Hapuka and Pines | | |
| [illegible].60 to 257.60 | Kekerengu I.B. and Wharanui | | |
| LENGTH GANG MN5 | | on | off |
| 306.10 to 306.65 | Weld Pass I.B. and Vernon | | |
| 308.50 to 309.30 | Weld Pass I.B. and Vernon | | |
| 342.70 to 343.00 | Tuamarina Sdg and Picton | | |

The "C" and "T" boards associated with these restrictions have a yellow reflectorised boarder attached.

B.K. Gordon.
NETWORK CONTROL OFFICER